LIMNOLOGY AND WATER QUALITY OF THE LAKE TAHOE REGION

A Guide for Planning

Prepared for

Tahoe Regional Planning Agency

and

Forest Service, U. S. Department of Agriculture

South Lake Tahoe, California

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ACKNOWLEDGMENTS

Establishment of the Tahoe Regional Planning Agency was consented to by the Congress through enactment of Public Law 91-148. On March 19, 1970, the governors of Nevada and California signed the Proclamation that proclaimed creation of the Tahoe Regional Planning Agency. Since the authorized staff of the Agency was small, it enlisted help from several committees composed of technical specialists and other citizens concerned with resource conservation and orderly development of the Tahoe environmental resources.

The planning effort has been aided greatly by generous cooperation from numerous federal, state, county, and municipal agencies and from several colleges and interested private individuals. Cooperating agencies included:

Federal:

Department of Agriculture: Forest Service; Soil Conservation Service

Department of Commerce: Environmental Sciences Services Administration

Department of Defense: Army Corps of Engineers

Department of Interior: The Bureaus of Mines, Outdoor Recreation, Reclamation, Sport Fisheries and Wildlife; Federal Water Quality Administration; and the Geological Survey

Department of Transportation: Coast Guard; Federal Highway Administration; Federal Aviation Administration

State:

California: The Resources Agency of California

Nevada: The Nevada Department of Conservation and Natural Resources

County and Municipal:

Carson City, Douglas, and Washoe Counties, Nevada; El Dorado and Placer Counties and City of South Lake Tahoe, California

Schools:

Foresta Institute; Sacramento State College; Tahoe College; University of California at Berkeley and Davis; University of Nevada; Desert Research Institute

Any publication that compiles and presents information from so large and disparate a group of contributors as this one does is susceptible to error, inconsistency, and omission. Sustained effort has been made to avoid these flaws; but if it has failed occasionally, the reader's forbearance is humbly solicited.

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This publication about the limnology and water quality of the Lake Tahoe Region was prepared by a committee of technical specialists appointed by the Tahoe Regional Planning Agency and the Forest Service's Tahoe Basin Planning Team. This committee acknowledges excellent cooperation and substantial help from many of the agencies listed on the preceding page and from numerous individuals concerned about the Tahoe environment. Members of this technical committee were:

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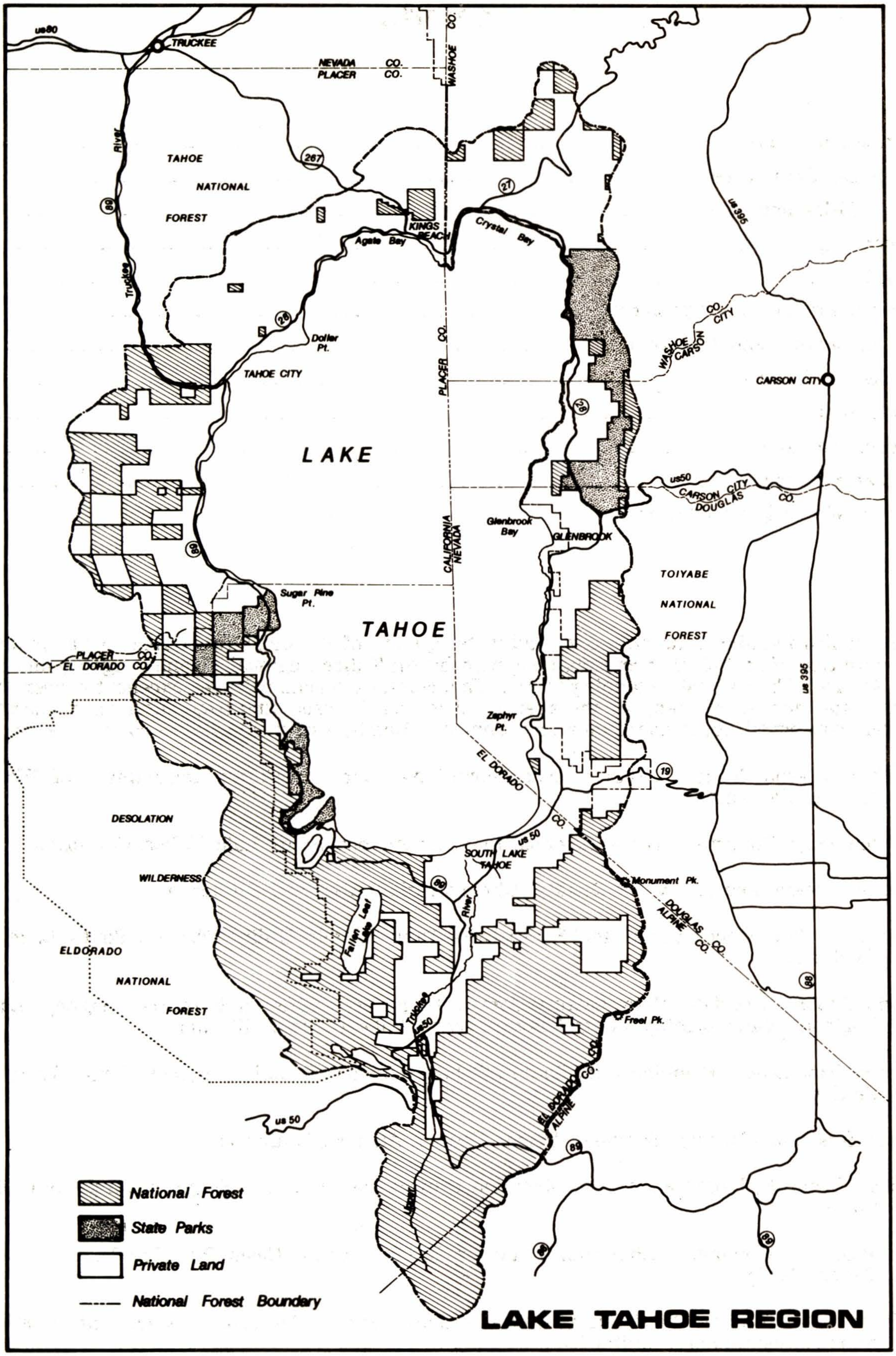

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PREFACE

Limnology is the scientific study of physical, chemical, biological, and bacteriological conditions in bodies of fresh water. This publication does not attempt a detailed explanation of limnology because it is a highly complex science. Since most of the data were collected on Lake Tahoe this report is limited to information about the lake. This report does not provide summaries of the detailed data already collected on Lake Tahoe since it requires a technical background to interpret this information properly.

Deterioration of a stream's or lake's water quality is usually the first sign that the natural processes that maintain the water quality are being disrupted. Thus collection and interpretation of limnological data is important if we are to meet the established goals for maintaining existing water quality. We reviewed numerous studies and reports in order to prepare a guide for planning but have included recommendations that we hope will help to protect and at the same time enable use of the unique water of the Tahoe Basin. Some of our recommendations duplicate some of those made in other planning guides that are also concerned about water quality.

INTRODUCTION

General Features of the Lake Tahoe Planning Area

Lake Tahoe and the mountainous, timber-covered basin immediately surrounding it provide one of the most beautiful environments in the Sierra Nevada and in the nation. The Lake itself, an irregular oval about 22 miles long by 12 miles wide, covers 191 square miles; it occupies a deep depression between crests of the Sierra Nevada and Carson ranges. Since its surface is 6,225 feet above mean sea level, Lake Tahoe is one of the largest high-altitude lakes in the world. The clarity and purity of its water are outstanding. In fact, protection of quality of the water in Lake Tahoe is a primary objective for effective control of the region's environment.

The spectacular scenery of the Lake Tahoe Region results from unique geological conditions that prevailed when the lake was formed. The basement rock is predominantly granite related to the rocks found throughout the Sierra Nevada. On the other hand, the geologic structure—the faulting that produced the lake basin itself—is related to the Basin Ranges that extend eastward from the Sierra to the Wasatch Range in Utah. The lake was formed by a natural dam—a great pile of andesitic mudflow breccia—across the north outlet.

Lake Tahoe is on the eastern boundary of that part of the Sierra Nevada that was extensively glaciated during the Pleistocene epoch. Huge valley glaciers moved down canyons along the western side of the lake, scouring away loose rock and building up great piles of morainal debris. Along the eastern side, glaciers developed only on the shaded side of the highest peaks; so most of this area was not glaciated. This accounts for the subdued rolling topography typical of the Carson Range, as contrasted to the rugged Sierran crest on the west side of the basin.

Climate of the region is strongly influenced by topography. Marine air from the Pacific Ocean, 150 miles to the west, drops its moisture (mostly as snow) as it rises over the crest of the Sierra. Average annual precipitation ranges from more than 50 inches on the western side of the region to about 25 inches along much of the eastern shoreline. The Weather Bureau at Tahoe City, on the west side, reports long-term average snowfall of 213 inches. The fairly long summers are comparatively cool; mean maximum temperature at Tahoe City in July over a 50-year period was 78°F. Winters are cold but seldom severe; mean daily minimum temperature for January over the same period was 17°F. The high elevation and cool temperatures result in a short growing season—an average of only 70 to 120 frost-free days per year at various points near the Lake.

Vegetation includes desert, montane, and alpine species typical of the eastern slopes of the Sierra. Pine and fir forests were heavily logged between 1860 and 1900 when demand for lumber and props for the Nevada silver mines was high. Even so, today the region has good stands of conifers between the Lake level and 9,000 feet, plus considerable areas covered by chaparral and other brush. On fairly level open areas that have a few inches of soil, grasses and other herbage flourish during the short growing season.

Numerous species of wildlife inhabit the Lake Tahoe region. Deer, bear, mountain lion, coyote, rabbit, raccoon, and several rodents are common. Land birds and waterfowl are present in small numbers consistent with available habitat. Heavy commercial fishing in the Lake around 1900 depleted native populations of cutthroat trout and whitefish, but kokanee salmon and several species of fish stocked from state hatcheries provide good recreational fishing today. Numerous tributary streams also provide sport fishing.

Soils are generally shallow and highly erodible—easily disturbed and slow to stabilize—but the soil is fairly deep in some bottom lands and glacial debris areas. The varied climate and highly erodible soils combine to make the Lake Tahoe region a fragile environment. Hence the ecological balance is easily upset. Whenever vegetation is removed, it is not soon replaced. Erosion by wind and water is a constant hazard; it damages pristine features of the Lake, including the spawning areas of native fish.

Changing Environment

Before the white man invaded this area about the middle of the 1800's, the somewhat nomadic

Washo Indian tribe inhabited it. Their name for the Lake, "Tahoe," has been variously translated as "big water," "high water," or "water in a high place." The first recorded white visitors were John Fremont's exploring party (1844); they were soon followed by the Forty-niners and other western migrants and adventurers.

During most of the following 100 years, Lake Tahoe was the summer recreation area for wealthy Californians, mostly from San Francisco and the Sacramento Valley. The few summer resorts, scattered stores, service stations, and restaurants hardly marred the natural beauty of the region.

Soon after World War II all this began to change. With increased general affluence, steadily and rapidly increasing numbers of vacationers began to visit the area; their visits gradually extended the "season" from summer to the full year. Establishment of year-round casinos at Stateline in 1955 and the phenomenal growth of winter sports added to the influx of both visitors and residents. By unofficial count in 1965, the region had nearly 29,000 yearlong residents—more than double the 1960 federal census figure. Present projections anticipate more than 50,000 residents by 1980 and an added summer population topping 250,000.

These projected increases in resident and transient populations will inevitably multiply and intensify the environment problems that already are plaguing the area; hence the crucial need for planning orderly development that can be sustained by the natural capacities of the region.

Administration and Governmental Responsibility

The Planning Area established by the Bi-State Planning Compact between the States of California and Nevada is a basin covering 327,878 acres, This includes the 122,628 acres of lake surface. Governmental jurisdiction over land in the Lake Tahoe Planning Area is complex (table 1). The Area is divided between California (Placer, El Dorado, and Alpine Counties) and Nevada (Washoe and Douglas counties and Carson City). This division of governmental responsibility makes it difficult to coordinate the administration of government in the Area in the interest of protecting the environment.

Nearly half (48.7 percent) of the land area is federally owned—chiefly in three National Forests totalling 107,762 acres. An additional 4.5 percent is state-owned, nearly all in State Parks. Thus about 53 percent of the land in the Planning Area is publicly owned.

Of nearly 75 miles of lake shoreline, about 18 percent is publicly owned. This is chiefly 8 miles belonging to the State of California and 5.5 miles in National Forests.

The Tahoe Regional Planning Agency began work as soon as the Governors of California and Nevada signed the proclamation creating the Bi-State Planning Agency. Public Law 91-148 had enumerated the dangers of deterioration of the natural environment at Tahoe and of the increasing demands on various natural resources and features of the region; also, it emphatically stated the need to maintain equilibrium between the region's natural endowment and limitations on one hand and the environment that man is creating. It recognized need for establishing "an area-wide planning agency with powers to adopt and enforce a regional plan of resource conservation and orderly development, to exercise effective environmental controls, and to perform other essential functions...."

TRPA was ordered to develop and adopt, within 18 months of its formation (i.e., by September 1971), a plan for regional development that would include separate plans for land use, transportation, conservation, recreational development, and public services and facilities, to name a few. The Agency was further directed to consider and to seek to harmonize the needs of the whole region with the plans of local governmental units and the existing land use plans of state and federal agencies.

Information in this publication is intended chiefly to guide regional planning.

Table 1.—**Land acreage, by jurisdiction, Lake Tahoe Regional Planning Area, February 1971**

Jurisdiction	Gross Acreage	Federal Land Acreage[1]	State Park Acreage	Private Land Acreage
Federal:				
Eldorado N. F.	85,518			
Tahoe N. F.	12,060			
Toiyabe N. F.	10,184			
Bur. of Reclamation	64			
	107,826	107,826		
State:				
California	3,552		3,552	
Nevada	6,047		6,047	
	9,599		9,599	
Counties and Cities:				
Alpine	4,170	4,170	0	0
El Dorado	96,887	81,348	3,535	12,004
Placer	46,291	12,124	17	34,150
Washoe	19,700	2,731	3,020	13,949
Douglas	23,538	6,619	709	16,210
Carson City	5,830	834	2,318	2,678
South Lake Tahoe City	5,482	0	0	5,482
Total land area	201,898	107,826	9,599	84,473
Lake Tahoe area[2]	122,628			
Small lakes area	3,352			
Total, Lake Tahoe Region Planning Area	327,878			

[1] National Forest land except 64 acres in Placer County controlled by the Bureau of Reclamation.
[2] At legal elevation of 6,229.1 feet above mean sea level.

GENERAL LIMNOLOGICAL CONSIDERATIONS

PHYSICAL

Water clarity is one of the Lake Tahoe's most unusual characteristics. A small white disc (secchi) has been visible in the water to a depth of 136 feet (Engineering-Science, Inc., June, 1963, p. 69). Lake Tahoe shares distinction for deep clean water with Crater Lake and Lake Baikal in Russia. Lake Tahoe is the second largest alpine lake in the world from the standpoints of area, depth, and volume. Its depth is 1645 feet, and its 122,000,000 acre-feet of water would cover the entire area of the state of California to a depth of approximately 14 inches.

"The top 6.1 feet (Elev. 6223.0 to 6229.1) of the Lake, with a valume of about 720,000 acre-feet serves as a storage reservoir for the Truckee Carson Irrigation District." (Engineering-Science, Inc., June, 1963, p. 4).

The annual hydrologic budget of the Lake Tahoe Basin (Crippen and Pavelka, 1970) is as follows:

Water source	**Acre-feet**
Precipitation on land	672,000
Losses from land	355,000
Inflow to lake	312,000
Evaporation from lake	352,000
Precipitation on lake	212,000
Diversions from basin	5,000
Outflow to Truckee River	172,000

These flows are the averages of all estimated or observed annual flows, i.e., the mean level.

The variation of water temperature significantly affects a lake's vertical currents and the nature of biological activity. Lake Tahoe usually has three layers of water with differing temperature characteristics. Air temperature and wind cause the depth of these layers to vary. When late autumn winds and lower air temperatures cool the lake surface, mixing of the upper 500 feet occurs and these layers merge. Temperature of the relatively warm upper layer, epilimnion, decreases very slowly with depth and may be as warm as 60°F to 70°F. It sometimes extends to a depth of 75 feet. The temperature of the next lower layer, thermocline, decreases rapidly as the depth increases. In late summer it can decrease in temperature from 65°F at a depth of 35 feet to 45°F at 180 feet. The temperature of the third layer, hypolimnion, changes very slowly with depth and is more uniform than the other two layers. The warmest temperatures of the upper portion of this deepest layer probably reach 50°F in later summer. At depths greater than 500 feet the temperature remains close to 39°F.

The amount of oxygen in the water is another factor that controls the nature of biological activity. Water in Lake Tahoe generally contains 7 to 11 mg/l (milligrams per liter) of dissolved oxygen (DO) at a range from 90 to 105 percent of saturation throughout the upper 500 feet. "For good growth and the general well-being of trout, salmon and their associated biota, DO concentrations should not be below 6 mg/l" (Federal Water Pollution). The pH (an index of the hydrogen ion activity) values range from 7.1 to 8.2 (California, Nevada and Federal Water Quality Administration, 1970, p. 16). The recommended pH range for aquatic life is between 6.0 and 9.0 (Federal Water Pollution Control Administration, 1968, p. 41).

Turbidity is caused by the presence of suspended matter such as clay, silt, finely divided organic matter, bacteria, plankton, and other microscopic organisms. It is an optical index of water clarity measured by a standard called Jackson turbidity units (JTU). Under normal conditions Lake Tahoe turbidity values ranged from 0.1 to 0.8 JTU between July 1968 and June 1969. During this same period General and Taylor Creeks ranged from 0.2 to 0.5 JTU, the Upper Truckee River from 2.0 to 4.4 JTU and Incline Creek from 3.5 to 24 JTU (California, Nevada and Federal Water Quality Administration, 1970, p. 17). The recommended upper limit for turbidity for cold water streams and lakes is 10 JTU (Federal Water Pollution Control Administration, 1968, p. 47). So, for the present at least, turbidity of the lake and most of its major tributaries is well below this maximum standard.

Settlable solids include both inorganic and organic materials. The inorganic components include sand, silt, and clay. The organic fraction can include such settlable materials as greases, oils, and tars. These solids can scour aquatic life from stream bottoms and thus reduce the food supply for fish. They also can cover up gravel and rubble-type bottoms thus eliminating spawning grounds and other habitat for aquatic life.

Very little information has been collected about either the extent or volume of settlable solids in the Tahoe Basin. "Since it is known that even minor deposits of settlable materials inhibit the growth of normal stream or lake flora and fauna, it is recommended that no settlable materials be added to those waters in quantities that adversely affect the natural biota" (Federal Water Pollution Control Administration, 1968, p. 48).

CHEMICAL

We do not yet know all the chemical elements necessary for plant growth. We do know that nitrogen, phosphorus, potassium, magnesium, calcium, manganese, iron, silicon, sulfur, oxygen, and carbon are important for plant growth. Abundance of nitrogen and phosphorus can contribute to plant growth if other conditions are favorable. The relative abundance and combined effect of nutrients as they occur to cause plant growth are more important than any individual element or nutrient. More extensive information has been collected on nitrogen and phosphorus than on the other elements. The 1968-1969 California-Nevada-Federal Water Quality Joint Investigation of Lake Tahoe showed that the mean value of phosphate or phosphorus did not exceed 5.8 mg/l (micrograms per liter) in the Lake or 17.8 mg/l in the tributaries. "The mean value of the sum of nitrate, nitrite and ammonia did not exceed 17.6 mg/l in the lake of 33.1 mg/l in the tributaries." Additional nutrients can cause excessive growth of aquatic plants and animals.

No data have been collected on the concentrations of chemicals such as the chlorinated hydrocarbons used for insecticides. Other dangerous chemicals are used in herbicides and defoliants. Any of these chemicals can damage or kill the aquatic organisms if they are applied in heavy concentrations.

BIOLOGICAL AND BACTERIOLOGICAL

Chlorophyll, the green coloring matter in plants, is directly related to the amount of photosynthesis. The food-manufacturing potential of a body of water can be indicated by measuring the chlorophyll per unit volume. Several types of organisms commonly found in large bodies of "pure" fresh water perform a variety of useful functions. Their influence on clarity of water is usually minor and localized, and some are important sources of food for fish and other aquatic inhabitants.

Algae are a major group of lower plants characterized by their photosynthetic ability and their diversity in shape, color, size, and habitat. Their basic function is to convert inorganic materials suspended in water into organic matter. Another beneficial role is removal of carbon dioxide from the water by photosynthesis and the production of oxygen. Growth of algae is part of a natural process; however, overproduction of some species can produce undesirable results such as unpleasant odors, scums, and loss of light to lower portions of the aquatic habitat. This overproduction can be caused by a sudden increase in nutrients either man-caused or naturally caused. Chlorophyll "a" concentrations in the Tahoe Basin are low. The Lake stations had a range of 0.07 to 0.41 mg/l and the tributary streams from 0.1 to 1.26 mg/l.

Phytoplankton are the minute, suspended organisms such as diatoms, desmids, and filamentaceous green algae. They are an important food source for other aquatic inhabitants. Total phytoplankton counts, ranging from 0 to 500 per ml., are relatively low. These counts can vary widely by season and location.

Zooplankton are small floating or swimming aquatic animals, most of which feed or graze on phytoplankton. They are an important source of food for certain fish. Sampling to date indicates no consistent increase in quantities of zooplankton. The maximum amount recorded is 4 per liter.

Periphyton are organisms that live attached to underwater surfaces. They are important in the recycling of phosphorus. Results of periphyton sampling are lacking because of the difficulty of sampling. Heavy periphyton growths have been observed over an extensive area near Tahoe City.

Benthos are organisms that live on or in the bottom of bodies of water. Some species are important food sources for fish, and various species of cladophora increase in number when nutrients increase and they can replace the original diverse benthic flora. The communities of invertebrates sampled in Lake Tahoe are typical of clear cold waters. The benthic sampling data collected since 1965-66 indicate little change in broad categories of benthic distribution. Benthic sampling of streams shows the highest diversity of forms in Taylor and General Creeks and the lowest in the Upper Truckee River and Incline Creek.

Certain bacteria have been used as indicators of sanitary quality of water. Fecal coliforms characteristically inhabit intestines of warm-blooded animals. The coliform group is used as an indicator of the sanitary quality of water to evaluate its potential for producing disease. "In general, the presence of fecal coliform organisms indicates recent and possibly dangerous pollution. The presence of other coliform organisms suggests less recent pollution or contributions from other sources of non-fecal origin." (Federal Water Pollution Control Administration, 1968, p. 22). Sampling data on coliform organisms collected from September 1968 to August 1969 show a range of 0 to greater than 200 colonies per 100 ml. for both the Lake and tributary streams. The suggested maximum limit for surface water supplies prior to treatment is 10,000/100 ml. for coliform organisms and 2,000/100 ml. for fecal coliform. The Lake water is markedly free of this type of pollution.

EUTROPHICATION AND POLLUTION

Eutrophication is the process of enrichment of a body of water which increases the organic content and causes turbid water and a muddy bottom. The organic content provides more nutrients and thus the means for increasing the biotic community. Over a long period of time this complex process can cause a lake to become a swamp or bog. Lake Tahoe is classified as an oligotropic lake. This means it has a deep clean water, a high dissolved oxygen content, is deficient in plant nutrients, and has a simple biotic community with short food chains. If Lake Tahoe's unique characteristics are worth protecting, then we must be constantly alert to detect indicators of accelerated eutrophication. If accelerated eutrophication is man-caused and identified as such, then procedures can be proposed to reduce this process. Table 2 summarizes the limnological considerations previously discussed.

TABLE 2—**Indicators of pollution or accelerated eutrophication**

Indicators	Ranges measured in Lake Tahoe and four selected tributaries[1]	Water quality objective (Set by California Regional Water Quality Control Board, Lahontan Region)	Comments
PHYSICAL			
Clarity (Light transmittance)	Secchi disc visible to a maximum depth of 37 meters (121 feet) Light transmissibility exceeded 100 meters (328 feet)	A vertical extinction coefficient loss less than 0.08 per meter measured at any depth below the first meter OR a turbidity less than 3 jtu at any point in the lake too shallow to determine a reliable extinction coefficient.	Clarity of the main body of water is still outstanding. Local shoreline influences cause some loss of clarity in near-shore areas of the Lake.
Temperature	From 60° to 70°F at the surface to a relatively constant 39°F at depths greater than 500 feet	None established	Water temperature can vary, dependent on many natural conditions. There is no detectable sign of pollution based on this indicator.
Dissolved oxygen	7 to 11 mg/l at a range of 90 to 105 percent of saturation	Minimum 90% saturation	There is no detectable sign of pollution based on this indicator.
pH	7.1 to 8.2	7.0 minimum to 8.4 maximum	There is no detectable sign of pollution based on this indicator.
Turbidity	Lake Tahoe 0.1 to 0.8 jtu T3 & T4[2]—General and Taylor Creeks 0.2 to 0.5 jtu T1—Upper Truckee River 2.0 to 4.4 jtu	Lake Tahoe 3 jtu	Lake Tahoe still has very low turbidity. General and Taylor Creeks represent flow from relatively undisturbed watersheds. Upper Truckee River and Incline Creek represent watersheds where urbanization is occurring at a level which is deteriorating

[1] General Creek, Taylor Creek, Upper Truckee River, and Incline Creek.

[2] These and following T-numbers indicate water quality observation stations on the map in the Appendix.

	T2—Incline Creek 3.5 to 24 jtu		existing water quality. This indicator shows signs of pollution of the streams and represents a significant threat to near-shore areas of the Lake.
Dissolved solids	Lake Tahoe 77 to 101 micrombos T1—Upper Truckee River 20 to 93 micrombos T2—Incline Creek 37 to 83 micrombos T3—General Creek 13 to 39 micrombos T4—Taylor Creek 22 to 31 micrombos	None established	This indicator shaws degree of mineralization. Waters of the Tahoe Basin are low in mineralization. There is no detectable sign of pollution based on this indicator.
Settlable solids	No measurements were made in the Lake for this indicator. A study by the State of California (1969) indicated total sediment yield of approximately 30,000 tons per year; 11,500 tons per year reaches the lower portions of the Trout Creek and Upper Truckee River Watersheds and Lake Tahoe. Roads contribute approximately 50% of this sediment. A study by Glancy (1971) of the Incline Village area indicated that three-fourths of the 10,000 tons of sediment reaching Lake Tahoe come from developed areas. It also indicated average sediment yield from developed areas during the 1970 water year delivered to the Lake was about 12 times greater than that from undeveloped areas.	Less than the concentration that would change the physical nature of the stream bottom or that would adversely affect the aquatic environment.	This indicator does show significant signs of pollution and that it is man-caused.

CHEMICAL		Mean in mg/l	Maximum	Mean	Maximum	
Phosphate as phosphorus (Reactive PO)	Lake Tahoe	5.8	10.5	10	20	Present level of the phosphorus nutrient for Lake Tahoe does not indicate signs of pollution unless some organisms are phosphorus-sensitive. Some limnologists feel that phosphorus rather than nitrogen may be the key nutrient. Present levels of phosphorus in both the Upper Truckee River and Incline Creek, if increased or maintained, can contribute to accelerated eutrophication.
	Upper Truckee	8.6	17.5			
	Incline Creek	17.8	25.0			
	General Creek	15.0	9.9			
	Taylor Creek	4.5	8.0			
Nitrate, nitrite, and ammonia	Lake Tahoe	21.1	27.6	150	300	Present level of the nitrogen nutrient for Lake Tahoe does not indicate signs of pollution unless some of the organisms are nitrogen-sensitive. The concentration of nitrogen in both the Upper Truckee River and Incline Creek if increased or maintained can contribute to accelerated eutrophication.
	Upper Truckee	31.4	57.6			
	Incline Creek	33.1	72.0			
	General Creek	21.9	28.0			
	Taylor Creek	26.9	48.6			
Chloride	Average value for Lake Tahoe 2.6 mg/l			Mean 3 mg/l Maximum 5 mg/l		There is no detectable sign of pollution based on this indicator.
Toxic substances (pesticides)	Not measured			At all times less than the concentrations toxic or harmful to aquatic life.		There are not any apparent problems at this time.

BIOLOGICAL AND BACTERIOLOGICAL			
Chlorophyll "a"	Data have been collected but not over a sufficient time period for valid interpretations.	A mean annual growth potential at any point in the lake not greater than twice the mean annual growth potential at the limnetic reference station.	During May 1969 a significant increase in chlorophyll concentrations in the lake near Camp Richardson coincided with an algae bloom in the southwest portion of the lake. If the frequency and the extent of these concentrations increase, then this indicator would be a positive sign of accelerated eutrophication.
Phytoplankton	Lake Tahoe, 0 to 508 organisms/ml Upper Truckee River, 79 to 523 organisms/ml Incline Creek, 48 to 381 organisms/ml General Creek, 0 to 48 organisms/ml Taylor Creek, 16 to 188 organisms/ml	A mean seasonal concentration not greater than 100 per milliliter and a maximum concentration not greater than 500 per milliliter at any point in the lake	Total phytoplankton counts are relatively low and have not been collected over a long enough time period to make valid generalizations. The relatively high counts in the Upper Truckee River and Incline Creek as compared to General and Taylor Creeks does suggest investigating increased urbanization as a cause.
Zooplankton	Maximum: 4 per liter	None established	The organisms collected comprise an association that is characteristic of Lake Tahoe. There is no detectable sign of pollution based on this indicator.
Periphyton	There is such wide range in diversity and population of species that valid ranges of counts cannot be made.	None established	The data to date are so varied that no generalizations can be made. During March and May of 1969, heavy periphyton growths were observed near Tahoe City. This growth may indicate ideal environmental growth conditions at that time. or we may be observing one of several consequences of increased urbanization.

Benthos	There can be such a wide range of populations for a single species throughout the lake that no valid variation can be determined. Species diversity was highest in Taylor and General Creeks and lowest in Upper Truckee River and Incline Creek. There were almost twice as many kinds of the classically sensitive stream forms (stoneflies, mayflies, and caddisflies) in Taylor and General Creeks as in the Upper Truckee River and Incline Creek.	None established	This indicator for the streams does show that erosion and sedimentation from the land on which development occurs is starting to degrade the aquatic habitat.
Coliform organisms	0 to greater than 200 colonies per 100 milliliters	The maximum coliform densities in MPN/100 ml varies from 15 to 700 depending on level of development on the lakeshore and distance from the shoreline.	The bacterial counts at most stations indicate the water is very pure and free from this type of pollution. The export of sewage from the Tahoe Basin to prevent contamination has been successful.

SOURCES OF POLLUTION

We must recognize that there is some naturally occurring erosion, sediment production, and delivery of nutrients to Lake Tahoe. Natural processes in the aquatic ecosystem are generally in adjustment with this natural input. If we exceed this natural input by adding sewage effluent to the streams or if we cause sediment yields that exceed the natural rates, then we upset the balance of the natural processes. If we are trying to maintain or protect the natural processes, then the man-caused increases that upset the natural processes can be considered as pollution.

Export of sewage from the Tahoe Basin has been accomplished; so there is little pollution from this source. The significantly increased sediment yields caused by development of lands within the Tahoe Basin are now a major source of pollution. Applications of fertilizers in excess of the plants' abilities to utilize them could also be another major source of nutrients. Surface water run-off from roads, roofs, and parking lots in developed areas can have the same potential as raw sewage for pollution of the receiving waters. There are other sources of pollution, but these are the major ones.

CONCLUSIONS

Our knowledge of the aquatic ecosystem in the Lake Tahoe Basin is so limited that we can only describe the ecosystem by broad trends and must be very careful in predicting the effects of increased human population in the basin.

Available data indicate that the waters of Lake Tahoe are still relatively pure. Some typical initial signs of pollution are appearing in some tributary streams and in several near-shore areas of the Lake. The similar deterioration of the aquatic ecosystem caused by urbanization in other areas is starting in the Tahoe Basin. We should not wait to see the final results before we take corrective and preventive action.

RECOMMENDATIONS

Some of the following recommendations have been made in the other planning guides, but we feel it is important to repeat them here for emphasis. Implementing these recommendations should help to preserve the Tahoe environment.

1. Immediately start stabilizing existing disturbed areas (by appropriate vegetative or mechanical means) that are contributing sedimentation.

2. Require complete soil stabilization on all new developments; this should be done concurrently with other construction activities.

3. Improve existing storm drainage facilities.

4. Require adequate storm drainage facilities in all new developments.

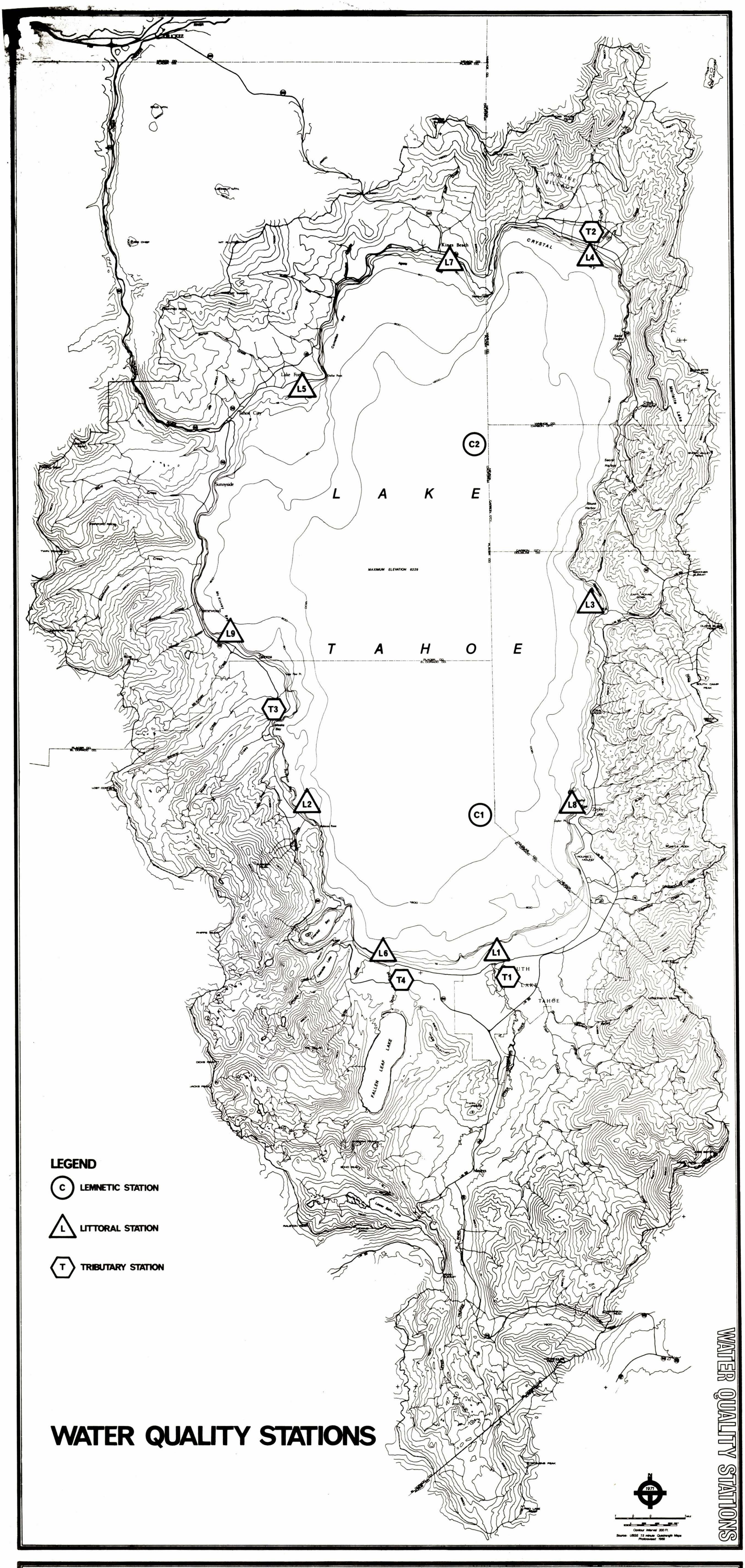
5. Consider reduction of area of impervious surfaces and retention of some storm water on-site to be percolated into the soil.

6. Prohibit discharge of petroleum and other toxicants into Lake Tahoe, streams, and storm drainage systems. Require oil traps at all garages and service stations and at parking lots near the Lake or tributary streams.

7. Determine the extent and use of fertilizers in the Tahoe Basin and how much of nutrients in fertilizers is delivered to the Lake. Then, if necessary, control the use of fertilizers.

8. Establish streamside environmental zones on each side of all annual streams. Zones should be wide enough to protect the aquatic habitat and are to be retained as open space.

9. Use only those pesticides that have been proved to be environmentally safe. Use pesticides that are selective and that have been approved by appropriate Fish and Game Departments and public health agencies.



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10. Do not introduce new species into the aquatic ecosystem until studies have shown that no adverse ecological effects would follow.

11. Continue the present California, Nevada, and Federal Joint Water Quality investigations of Lake Tahoe.

12. Investigate and define the relative yield of nutrients from the major land types and how these nutrients are used by the vegetation. For example, vegetation removal and the subsequent increase in nutrient yield from soils of volcanic origin in the northwest portion of the basin may be contributing to the increased aquatic growth and turbidity in the Lake's water near Tahoe City.

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This publication is one of a group issued jointly by the Tahoe Regional Planning Agency and the USDA Forest Service. Each publication describes and inventories a natural resource or other characteristic that is significant to the total environment of the Lake Tahoe Region; it attempts to show the hazards incidental to improperly planned development of the area and to provide information helpful in designing controls that must be implemented if the scenic beauty of the Lake Tahoe Region is to be preserved and its other natural resources are to be conserved. These publications are not exhaustive treatises of their subjects, but they highlight the known significant information and data useful in the planning effort underway. Subjects of publications in this series are:

Climate and Air Quality of the Lake Tahoe Region

Cultural and Historical Significance of the Lake Tahoe Region

Land Resources of the Lake Tahoe Region

Fisheries of Lake Tahoe and Its Tributary Waters

Geology and Geomorphology of the Lake Tahoe Region

Hydrology and Water Resources of the Lake Tahoe Region

Limnology and Water Quality of Lake Tahoe and Tributary Waters

Recreational Resources of the Lake Tahoe Region

Wildlife of the Lake Tahoe Region

Soils of the Lake Tahoe Region

Vegetation of the Lake Tahoe Region

Scenic Analyses of the Lake Tahoe Region

Because of the heavy expense of publication and because these reports are designed chiefly for use by planners, supplies are not available for general public distribution.

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